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DRAO CHARACTERISTICS AND SUITABILITY OF THREE-FOOT LONG PARACH--ETC(U)  
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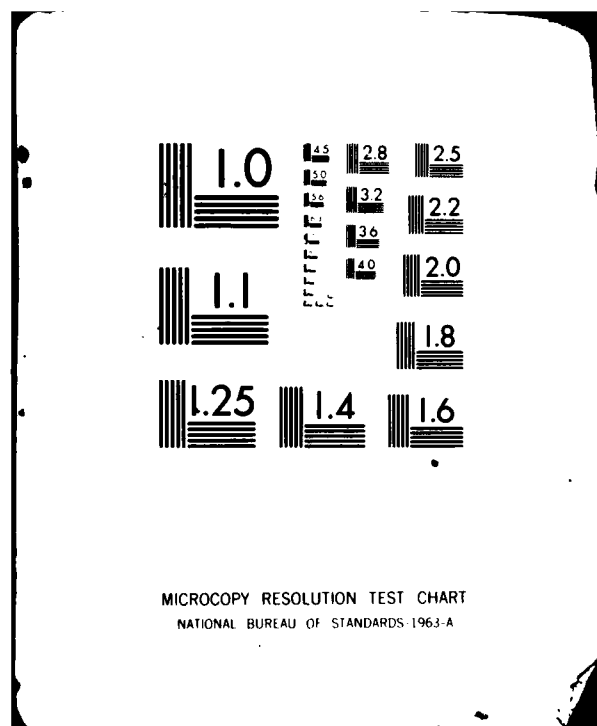
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DRAG CHARACTERISTICS AND SUITABILITY  
OF THREE-FOOT LONG PARACHUTE DECELERATORS

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ABSTRACT

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Air drop and wind tunnel tests were conducted to verify the stability of sonobuoys with decelerators limited to a total length of three feet. This limitation was established for safety reasons. The existing decelerator systems are configured to a length of 5 to 12 feet, with cross-type canopies varying in area from 1.5 to 3.5 square feet. Sonobuoys are blunt nose right circular cylinders, 4-7/8 inches in diameter, 36 inches long ranging in weight from 12 to 39 pounds. Testing established that suitable stability could be achieved using a three-foot long decelerator. Drag coefficient, opening load, high altitude air descent time and stability data were also determined for three-foot long decelerators.

INTRODUCTION

Sonobuoys are expendable electro-acoustic sensors which are air deployed from Navy fixed and rotary wing aircraft. The air deployed body is blunt nosed, cylindrically shaped 4-7/8 inches in diameter 36 inches long ranging in weight from 12 to 39 pounds. The center of gravity varies randomly between 13 to 18 inches from the end opposite the decelerator. A Ballistic Coefficient (B), a ratio of weight to effective drag area ratio of  $18 \pm 1.0$  pounds per square foot is specified for sonobuoys weighing between 34 to 39 pounds and  $12.3 \pm 1.0$  for all other weights.

The launch angle of the sonobuoy relative to the airstream varies between fixed and rotary wing aircraft. The fixed wing orientation is down and aft  $45^\circ$  from the horizontal. Rotary wing launches are either vertical straight down or horizontal  $90^\circ$  from the direction of flight.

After launch a decelerator system is deployed which must sufficiently stabilize the sonobuoy prior to water impact. The stability must be adequate enough so that the electro-acoustic and hydromechanical systems function normally after water impact.

Currently the decelerator systems utilize cross-type parachutes which have canopy areas varying between 1.5 and 3.5 square feet. The length to width ratio of the canopy is 3 to 1. The uninflated length of the decelerator system, i.e., the length of the fully extended uninflated decelerator from the attachment point on the buoy to the tip of the uninflated canopy vary from 5 to 12 feet with no relation to area. Due to a safety of flight requirement, a maximum three-foot limitation was placed on the uninflated decelerator total length.

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A program of wind tunnel and air drop testing was conducted to verify if the performance and configuration requirements could be met. The effect of close coupling the parachute to the store is of particular interest. Decelerator systems up to 12 feet in length and a variety of canopy areas were tested for comparison.

#### WIND TUNNEL TESTING

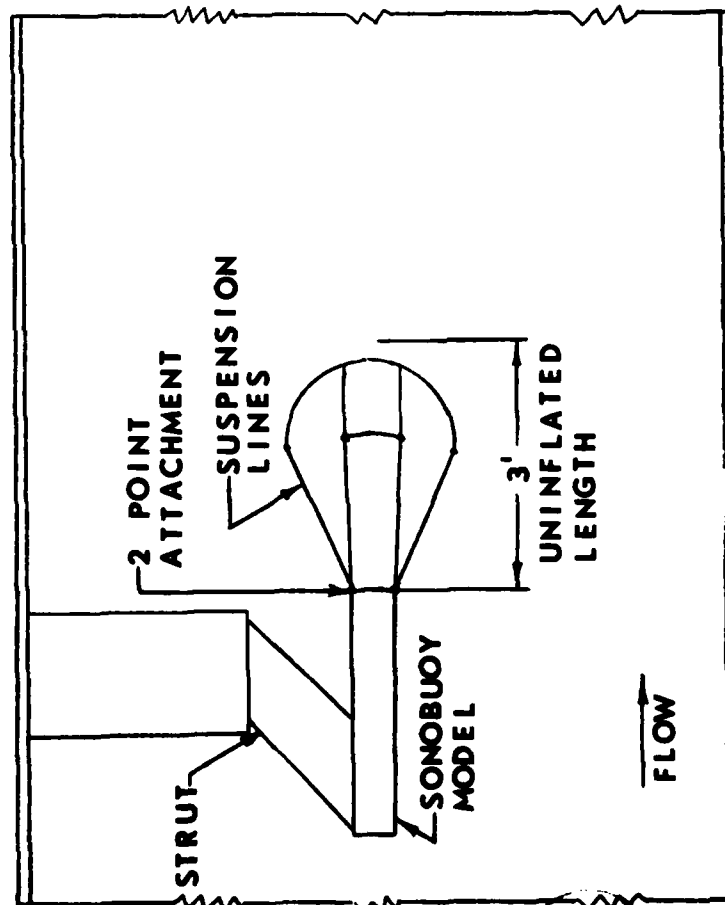
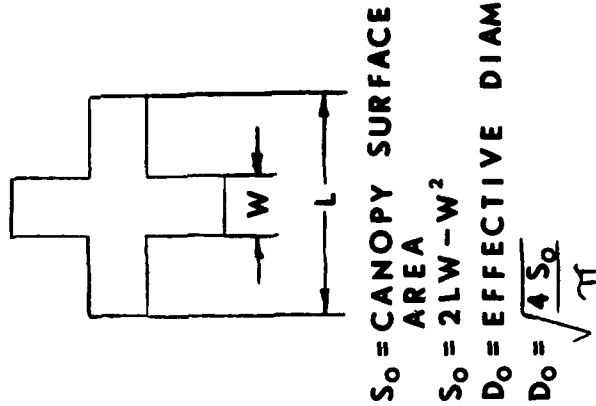
A test program was conducted at the National Aeronautics and Space Administration (NASA), Lewis Research Center's 10 foot x 10 foot wind tunnel to evaluate decelerator characteristics as a function of total system length. The wind tunnel test model set-up is shown in Figure 1. A full scale model of the sonobuoy was placed in the wind tunnel parallel to the direction of flow. It is fixed to the ceiling by a strut. The parachute is stowed in the aft end of the model and is deployed on command. A captivated windflap is released into the airstream when a dynamic pressure of 150 pounds per square foot, the wind tunnel maximum, is reached. The windflap deploys the parachute from its stowage location in the model initiating parachute inflation. The tunnel drive is shut down and a braking system is activated to slow the tunnel.

A load cell is used in the model to measure parachute loading only. The initial one second of load cell data is displayed on a high speed visicorder to evaluate opening loading. Load cell data and tunnel conditions are recorded as the tunnel decelerates for further evaluation.

The decelerators tested had canopies made of lightweight nylon material predominantly 2.25 ounce/square yard. Ten percent of the canopies had 1.1 ounce/square yard material. The chutes were packed in a deployment bag and a line first deployment method was used. Some basic cross-chute configuration details are shown in Figure 1. To achieve higher effective drag area ( $C_d S_o$ ) the number of suspension lines was varied from 2 to 3 per parachute panel and evaluated. The total quantity of runs made in the wind tunnel was approximately 100 including a combination of decelerator lengths and canopy area.

Since the total decelerator length requirement is a unique design constraint a more conventional design parameter, suspension line length/canopy effective diameter ( $L_g/D_o$ ), is introduced at this time and will be included in the data.

Examples of recorded opening load data are shown in Figures 2 and 3 for system total lengths equal to three feet and greater than three feet respectively. These curves represent some of the more severe loading measured. There appeared to be no clear cut trend between snatch load and opening load factor, based as average load, related to length. About 5 percent of the snatch loads observed were 2 to 3 times the average load and appeared not to be related to decelerator length. The other snatch loads were less than the average load measured. The opening load factor varied between 1.3 and 1.5 and it also appeared to be independent of length. Although line first deployments were used in every test it seems that these systems are sensitive to packing technique, which may account for some of the high snatch loading. The opening load factor measured should



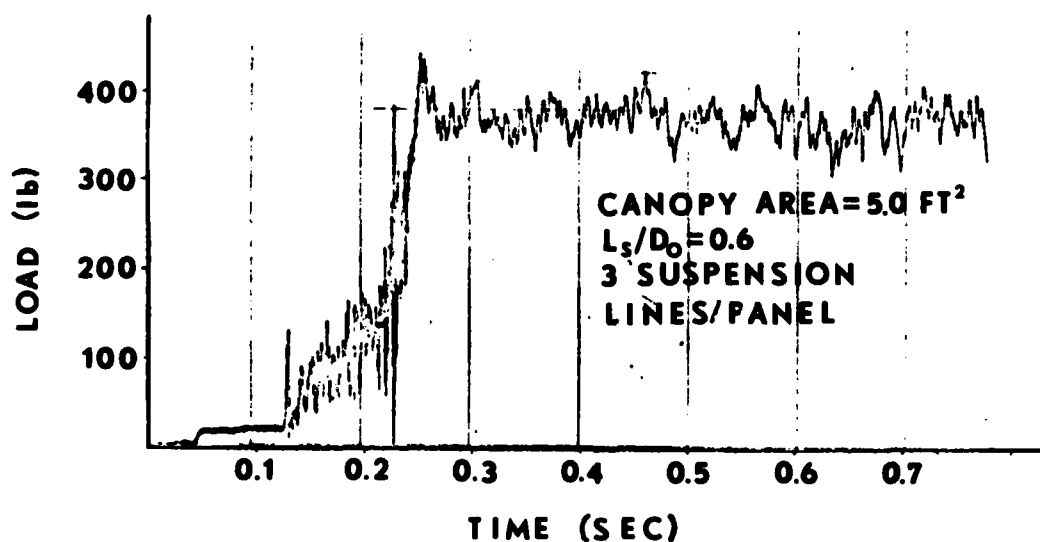
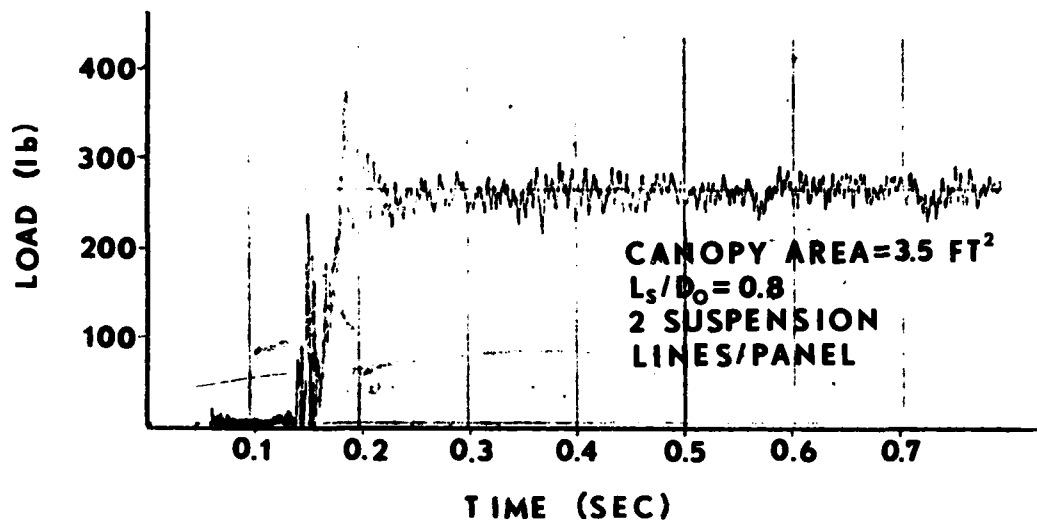
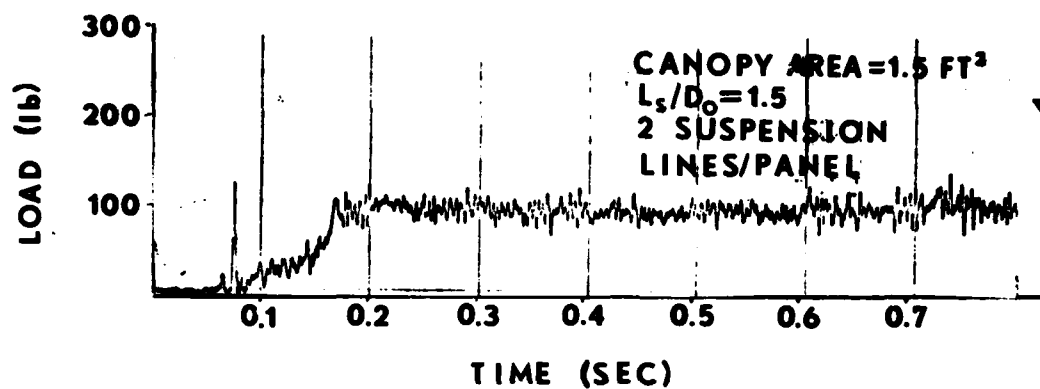
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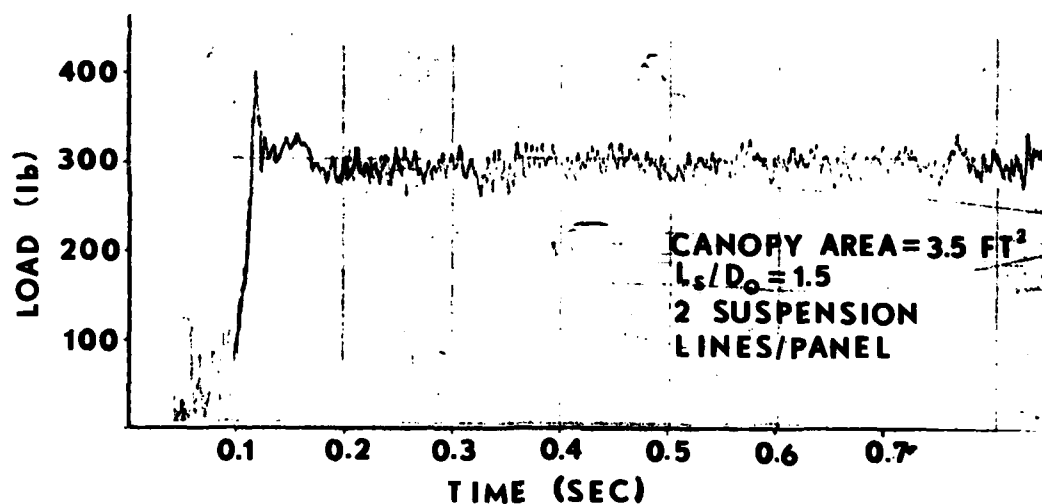
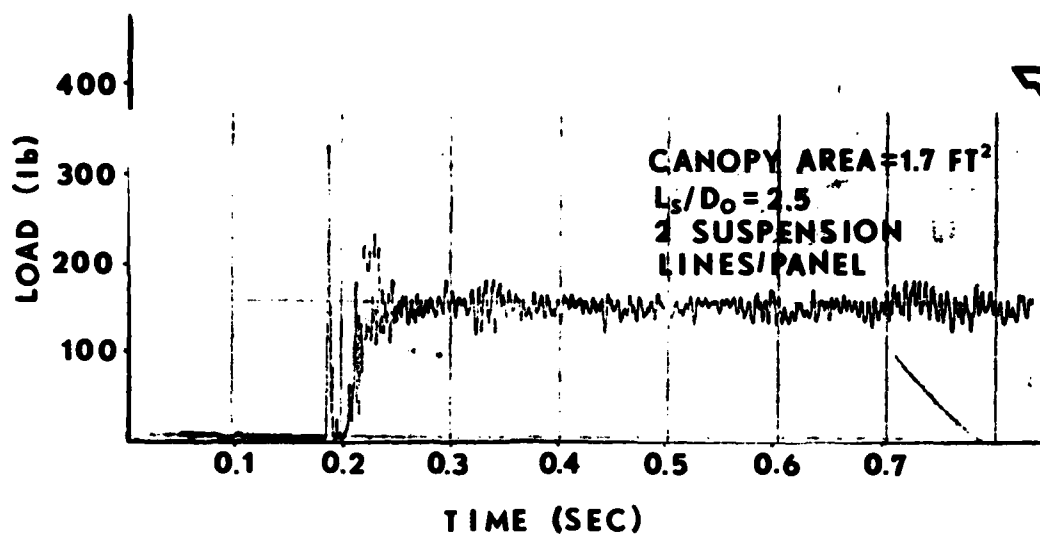
# WIND TUNNEL ARRANGEMENT

**FIGURE 1**



DECELERATOR INFLATION EVENT  
SYSTEM LENGTH = 3 FEET

FIGURE 2



DECELERATOR INFLATION EVENT  
SYSTEM LENGTH > 3 FEET

FIGURE 3

influence design practices if these types of chutes are used.

Drag Coefficient ( $C_d$ ) data was then computed based on drag measured at Equilibrium Velocity ( $V_e$ ) for the specified Ballistic Coefficient. Figure 4 shows the relationship between cross chute  $C_d$  and  $L_s/D_o$ , area and number of suspension lines. Figure 5, which applies to the three-foot maximum decelerator length requirement, shows how  $C_d$  varies as a function of decelerator area and number of suspension lines per panel. The  $L_s/D_o$  relationship is also shown to comply with popular design practices. It was noted after reviewing all data that the weight of the material has no appreciable effect on  $C_d$ ; therefore it was not included in Figures 4 and 5.

#### HIGH ALTITUDE TESTING

A series of high altitude air drop tests from 25,000 feet was conducted at NASA Wallops Flight Center to determine how air descent time is related to the sonobuoy weight to effective drag area ratio. A variety of buoy weights and weight to effective drag area ratios were tested. The altitude of the drop aircraft and the altitude/time history of the buoy air descent was determined by radar. Ten samples of each configuration was tested and the average time for that sample was used for  $C_d$  computation.

A drag coefficient was computed based on air descent time, altitude, decelerator size and sonobuoy weight by varying the drag coefficient in a computer program until the average time measured was achieved. Figure 6 shows a comparison of the  $C_d$  computed based on air descent time and the  $C_d$  measured in the wind tunnel for the same configuration. All systems met the three-foot maximum length decelerator requirement.

This data shows that for a given sonobuoy weight, as the ballistic coefficient is reduced, the sonobuoy is more stable. This is shown by the air descent time which compares more favorably with a predicted time based on wind tunnel measured drag coefficient.

#### LOW ALTITUDE TEST

A series of air drop tests were conducted at the Naval Air Development Center Field Station, Key West, Florida. The purpose was to determine if the sonobuoy could be adequately stabilized prior to water impact when launched from low altitude. The launch points used are shown on Table I.

TABLE I

#### LOW ALTITUDE TEST POINTS

Altitude (Feet)	Airspeed (KIAS)
1,500	300
500	350
200	300
150	200





# CROSS CHUTE $C_D$ vs $L_S/D_O$

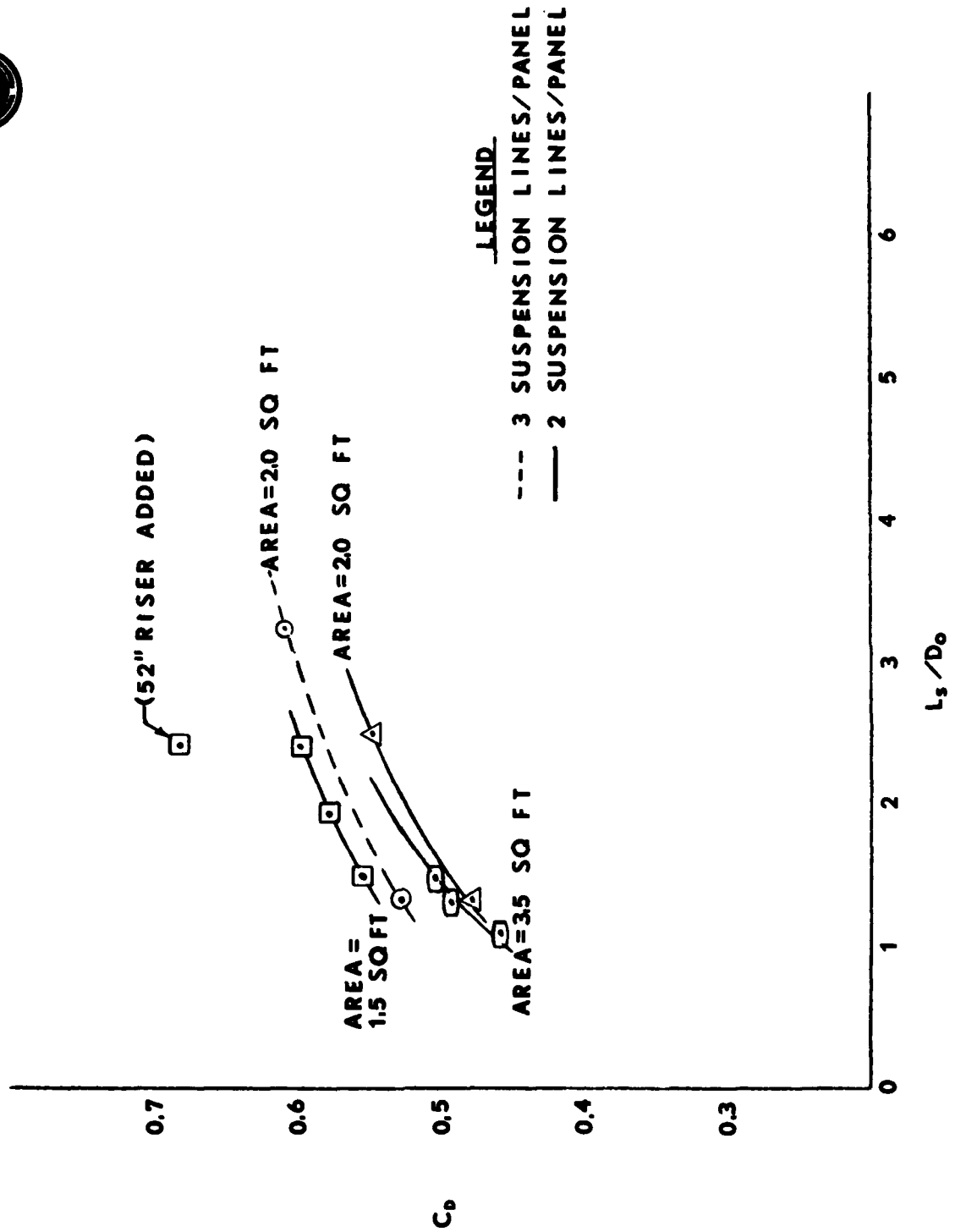


FIGURE 4

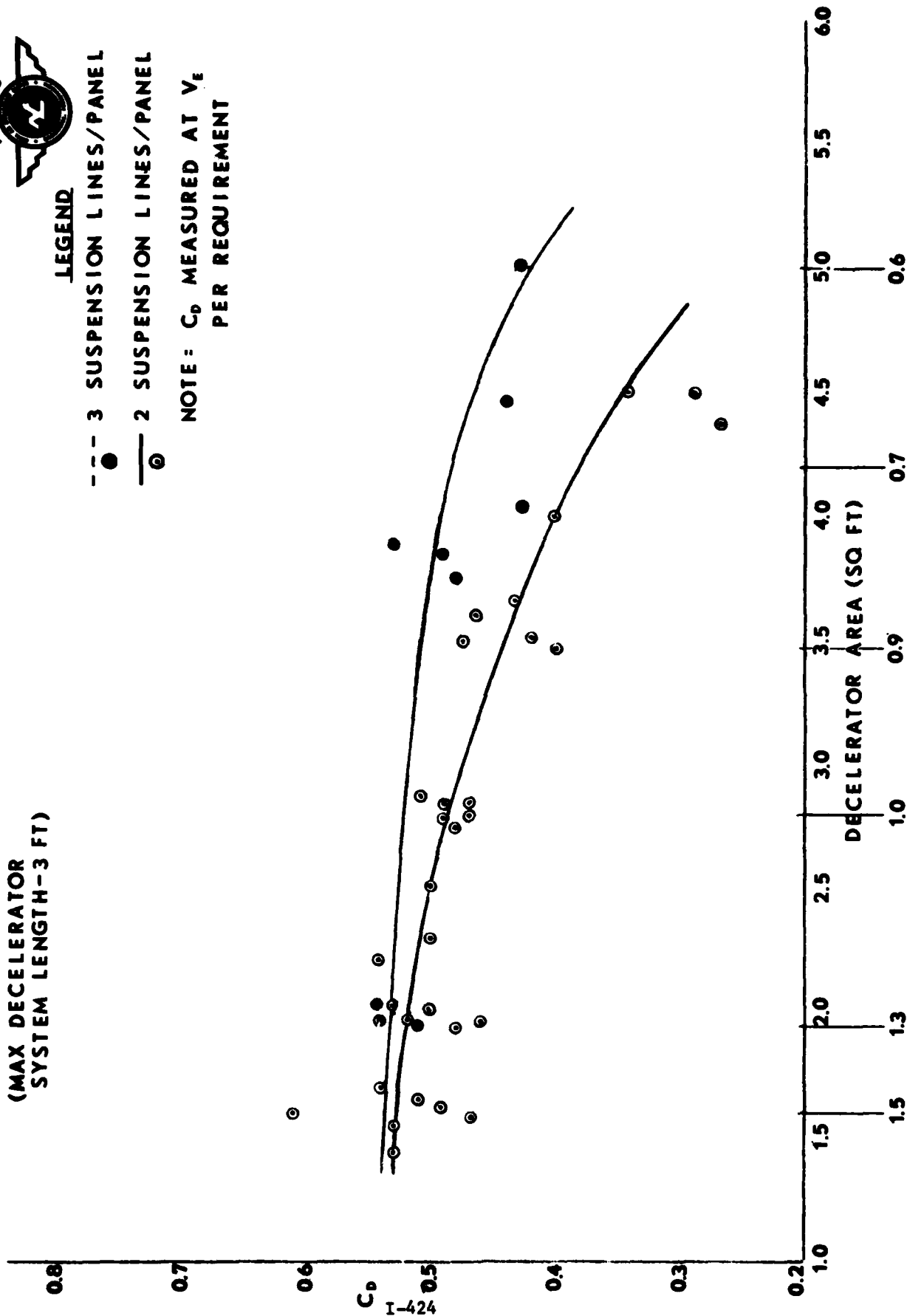
CROSS CHUTE  $C_D$  VS AREA CHARACTERISTIC  
(MAX DECELERATOR  
SYSTEM LENGTH-3 FT)



LEGEND

- 3 SUSPENSION LINES/PANEL
- 
- 2 SUSPENSION LINES/PANEL
- 

NOTE:  $C_D$  MEASURED AT  $V_E$   
PER REQUIREMENT

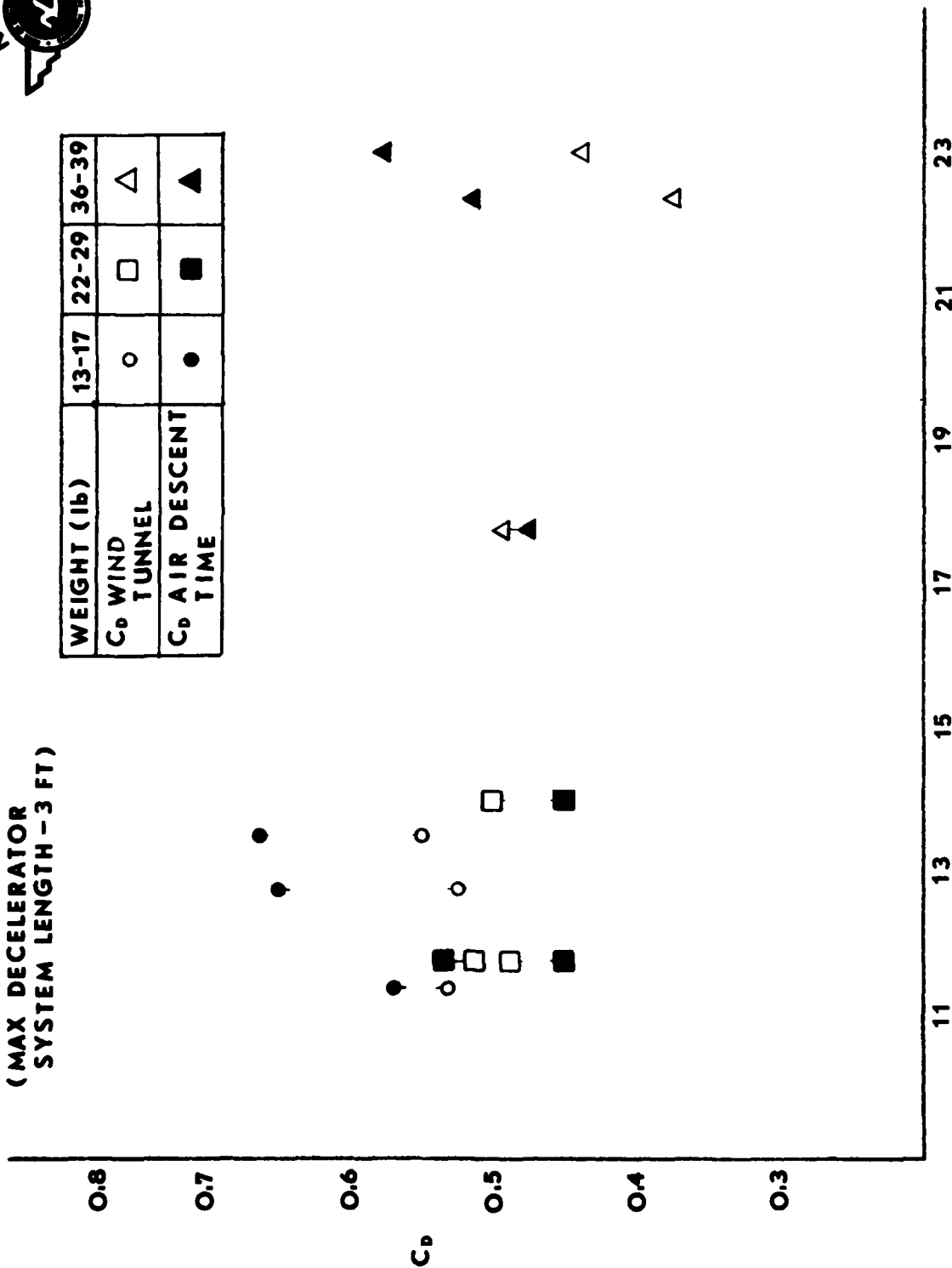


$L_s/D_0$   
FIGURE 5

# **CROSS CHUTE $C_D$ VS $\beta$** (MAX DECELERATOR SYSTEM LENGTH - 3 FT)



WEIGHT (lb)	13-17	22-29	36-39
$C_D$ WIND TUNNEL	○	□	△
$C_D$ AIR DESCENT TIME	●	■	▲



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FIGURE 6

The time for store stabilization is minimal at the lower test altitudes. The stability at water entry must be adequate enough so the sonobuoy internal components could function after impact. Sonobuoys ranging in weight from 14 to 39 pounds were dropped from each launch point. The sample size in all cases was five.

The results of the tests showed that decelerators sized within the established constraints could provide sufficient stability. The shallowest water entry angle that the buoys were exposed to was  $35^{\circ}$  relative to the water surface. The stability was such that the sonobuoy body oscillations about the trajectory angle varied by no more than  $\pm 5^{\circ}$ . The sonobuoy in-water functioning was not affected.

#### CONCLUSION

Blunt nose stores ranging in weight from 12 to 39 pounds can be adequately stabilized with a cross-type parachute sized to the ballistic coefficient and total length requirements outlined above. Useful decelerator design information is compiled herein which would have a variety of applications.

